Next Generation Monthly Products for Terra

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GFDL, Princeton, NJ, May 3-5, 2005

Outline

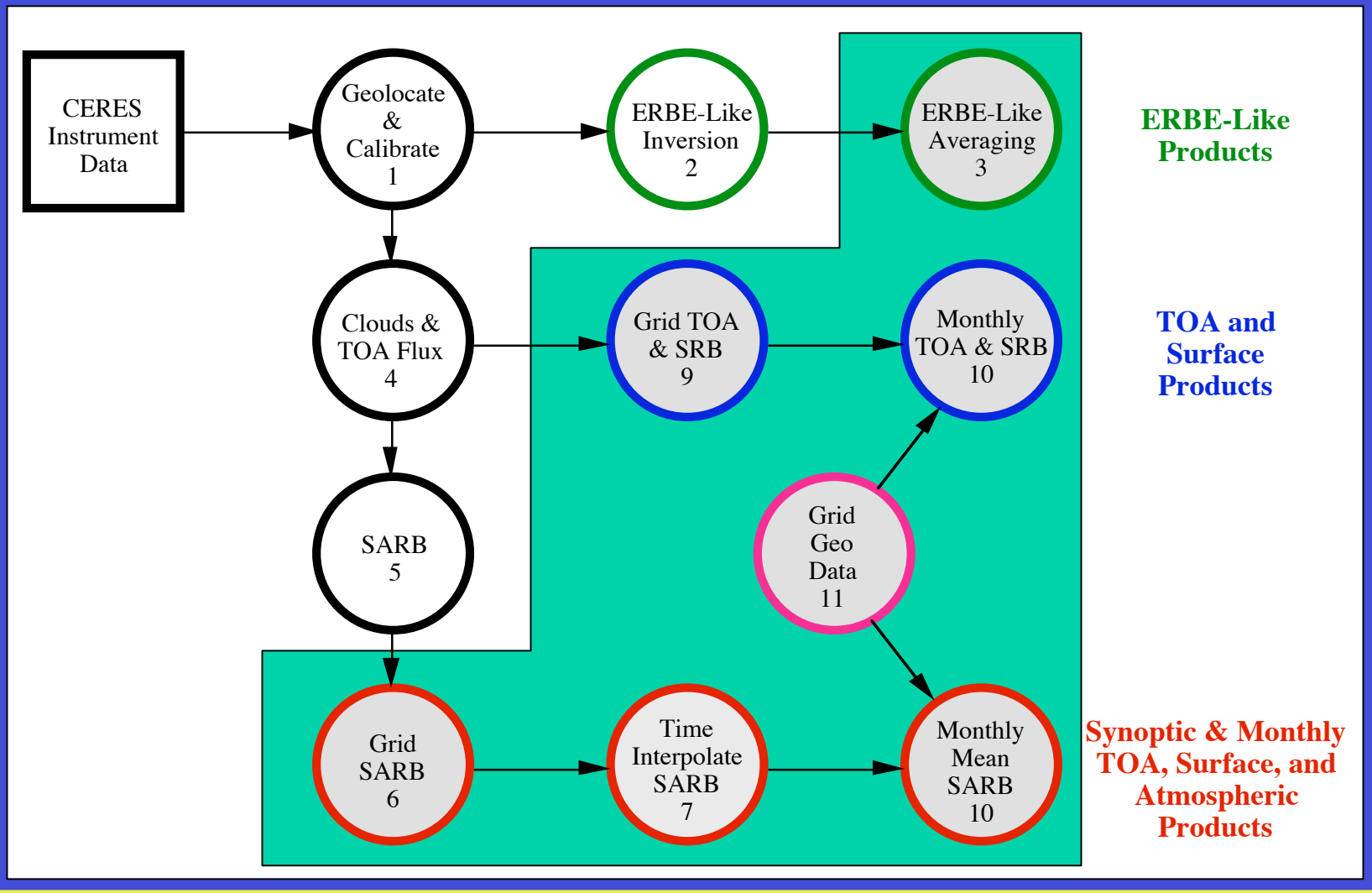
- Globally Gridded CERES Instantaneous and Time-Averaged Products
  - What CERES gridded products are available?
  - How do I know which one is best for my research?
- CERES Temporal Interpolation
  - How does it work?
  - How successfully do we remove temporal sampling errors?
  - What products are currently available?

CERES Temporal Interpolation and Spatial Averaging (TISA)

Goals

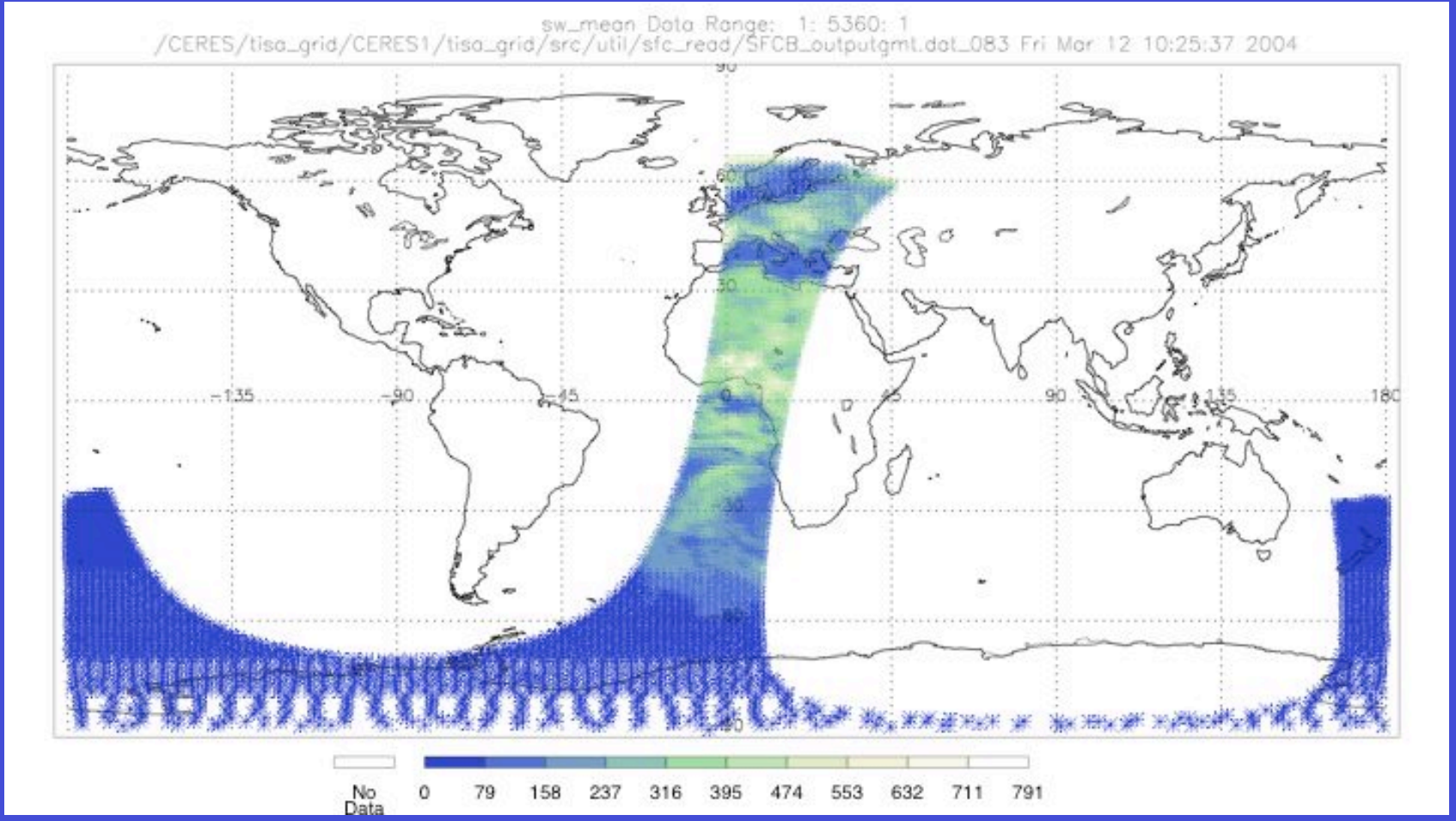
- Produce climate quality monthly and daily means
  - Must maintain calibration
- Eliminate temporal sampling errors
- Retain consistency among TOA fluxes, cloud properties and surface fluxes
- Produce synoptic maps of TOA, surface, and atmospheric flux

Where TISA Fits Into CERES Processing



Start with Gridded CERES Observations

One hour of CERES TOA SW Fluxes

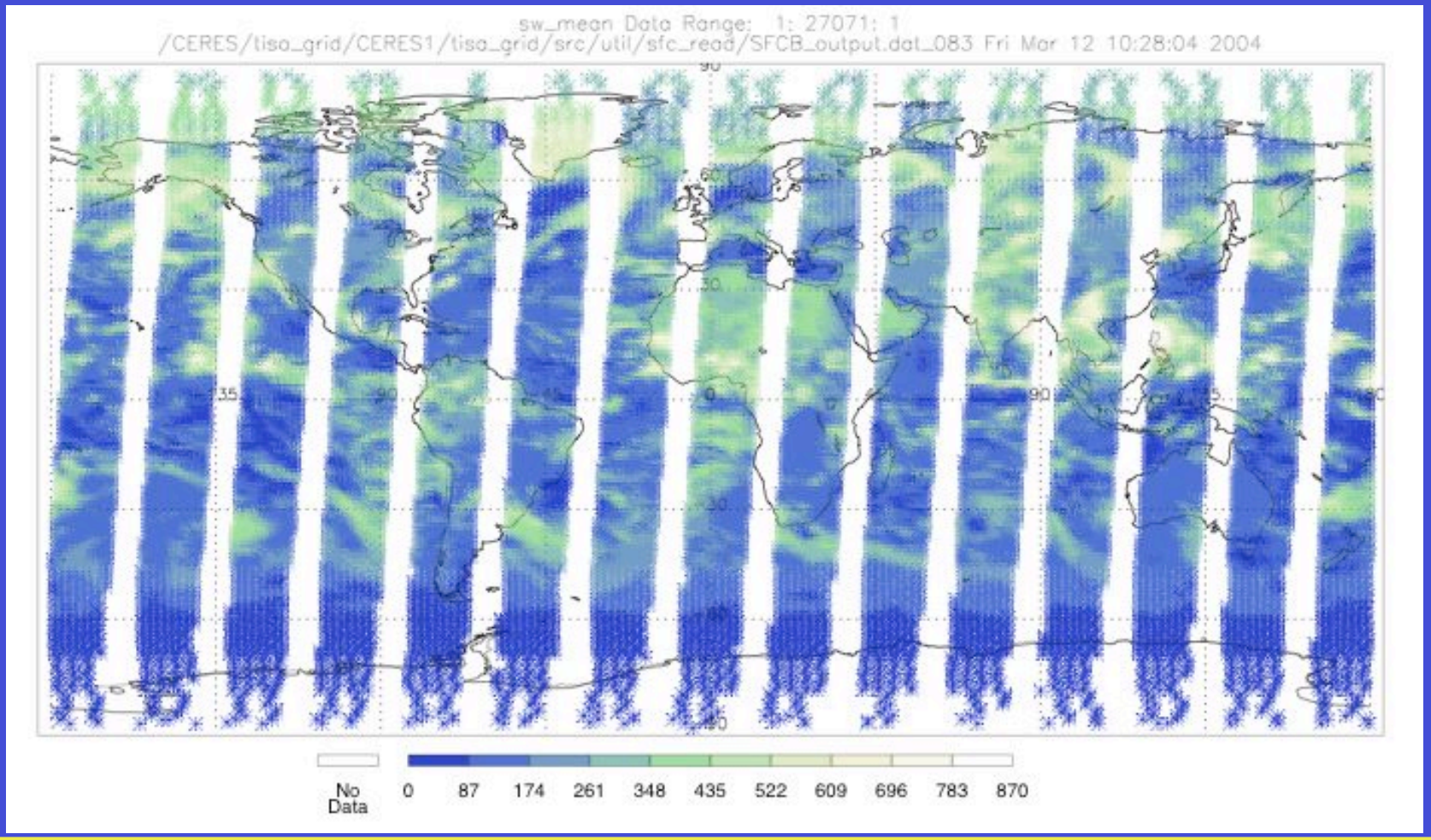


CERES Instantaneous Gridded Data Products

CERES Data Product	TRMM	Terra	Aqua	ERBElike Product	TOA and Surface Product	Atmosphere Product
ES9 (ERBElike Monthly Regional Averages)	Ed2	Ed2	Ed2	X		
SFC (Monthly Gridded TOA/Surface Fluxes and Clouds)	Ed2B	Ed2C	Ed1B		X	
FSW (Monthly Gridded Radiative Fluxes and Clouds)	Ed2C	Ed2C	Beta1			X
SYN (Synoptic Radiative Fluxes and Clouds)	Beta	Beta2	2005 Beta1			X

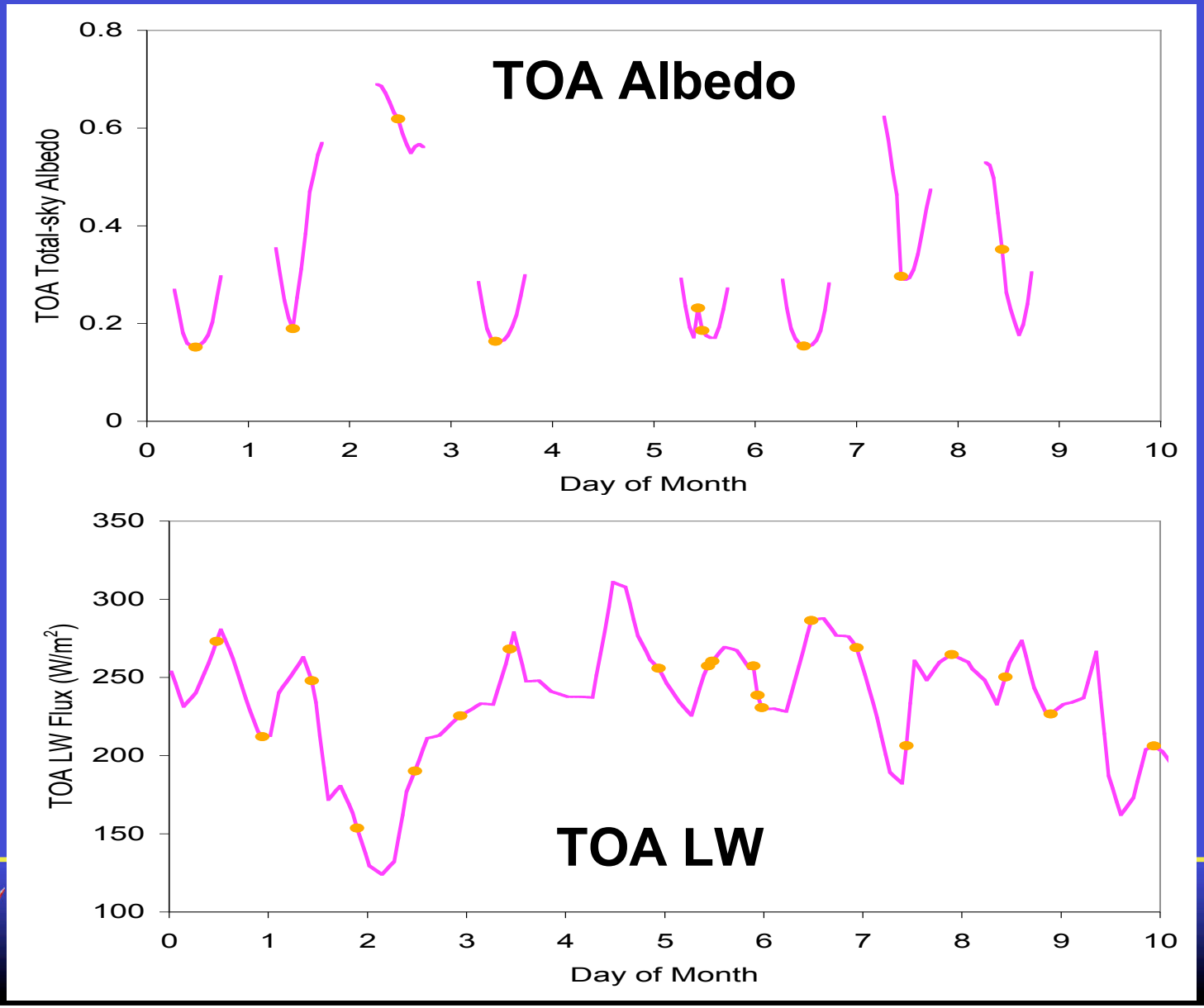
Organize Regional Data by Time

One day of CERES TOA SW Fluxes at 10:30 LT



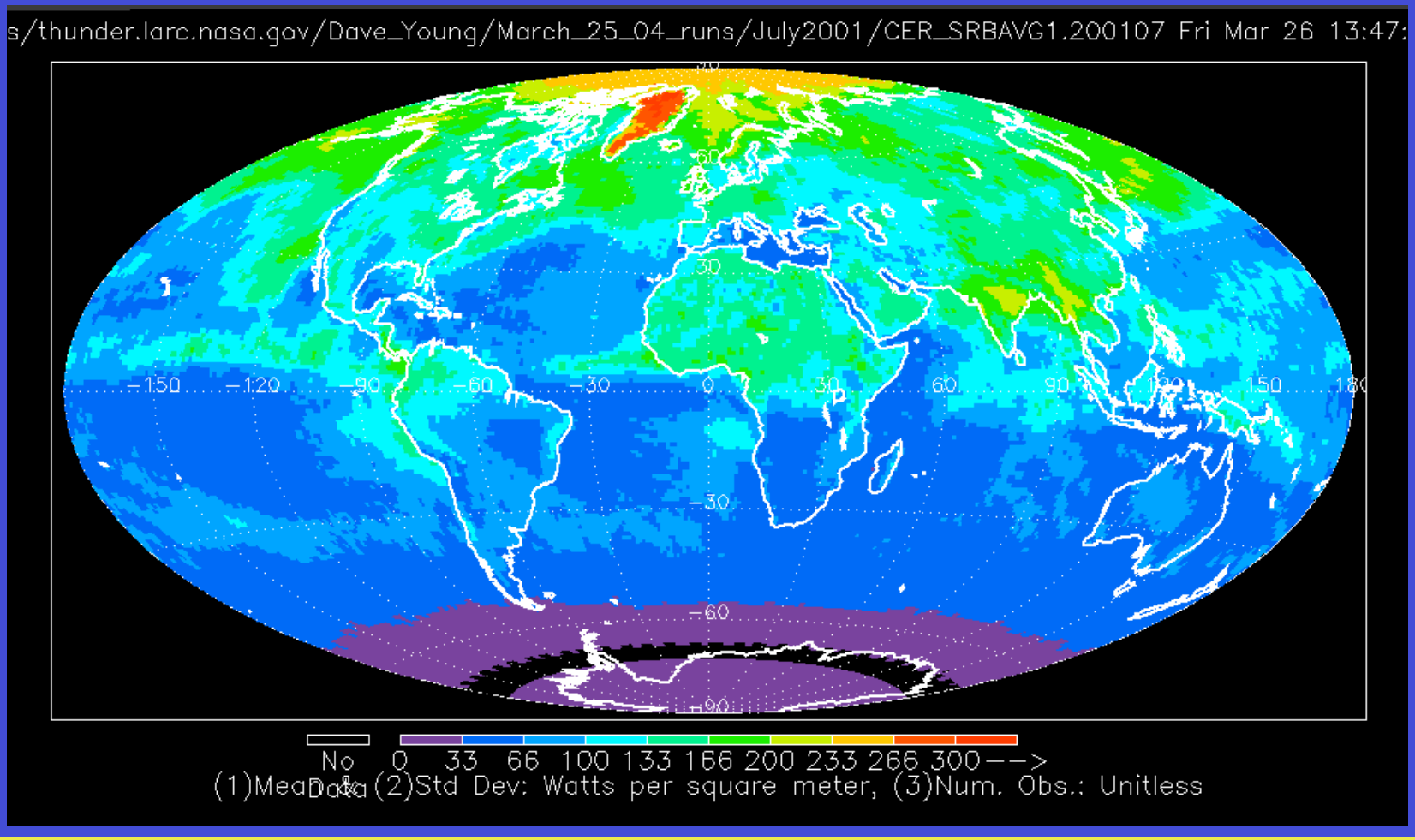
Interpolate Fluxes and Clouds over Month

Regional Time Series of Flux from Terra over ARM SGP



Create Temporally Interpolated and Averaged Data Products

TOA SW Flux Terra FM-1 July 2001



CERES Monthly Gridded Average Data Products

CERES Data Product	TRMM	Terra	Aqua	ERBElike Product	TOA and Surface Product	Atmosphere Product
ES9 (ERBElike Monthly Regional Averages)	Ed2	Ed2	Ed2	X		
ES4 (ERBElike Monthly Geographical Averages)	Ed2	Ed2	Ed2	X		
SRBAVG (Monthly TOA/Surface Averages)	Ed2B	Ed2C	2005 Beta1		X	
AVG (Monthly Regional Radiative Fluxes and Clouds)	2005 Beta1	2005 Beta2	2005 Beta1			X
ZAVG (Monthly Zonal and Global Radiative Fluxes and Clouds)	2005 Beta1	2005 Beta2	2005 Beta1			X

CERES Monthly Mean Products

SYN/AVG

- Uses GEO-enhanced interpolation to produce global synoptic flux and cloud fields
- Atmospheric Fluxes
- Pristine/Clear Fluxes
- Complete RT results

SRBAVG

- Takes advantage of improved CERES fluxes
- Uses improved temporal interpolation to remove sampling effects
- 1.0° grid
- TOA and surface fluxes
- Detailed cloud properties
- Product contains GEO and nonGEO monthly means

BDS	BDS	BDS
ES8	SSF	CRS
---	SFC	FSW
---	---	SYN
ES4	SRBAVG	AVG
ES4	SRBAVG	AVG
ES4	SRBAVG	AVG

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http://snowdog.larc.nasa.gov/cgi-bin/rose/wd

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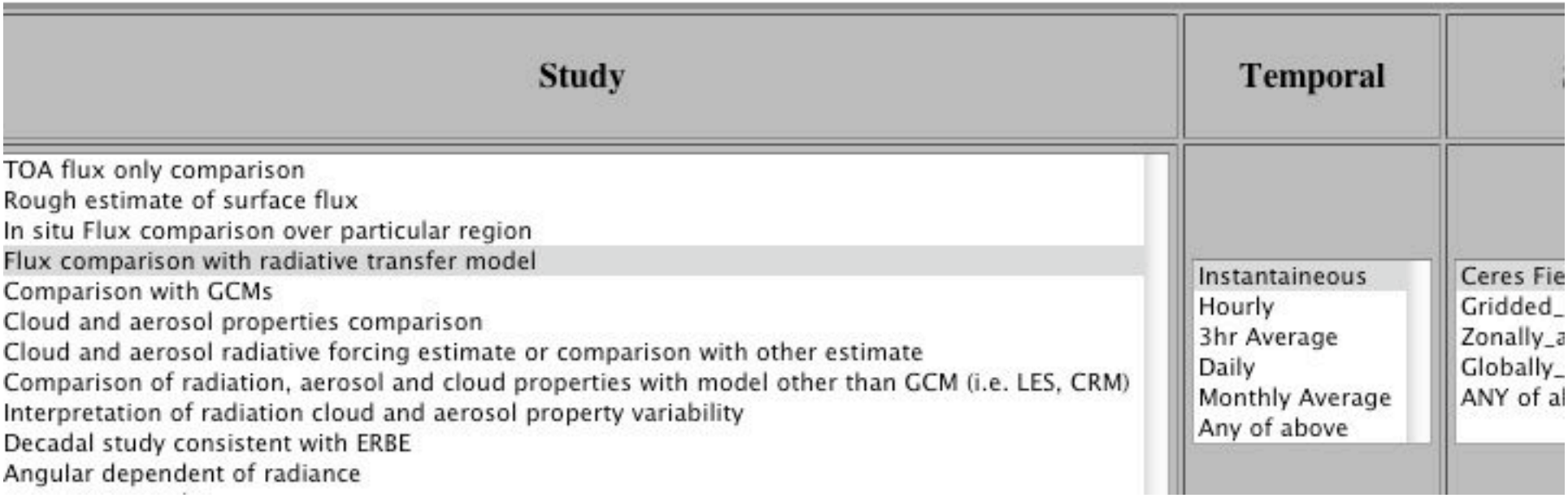
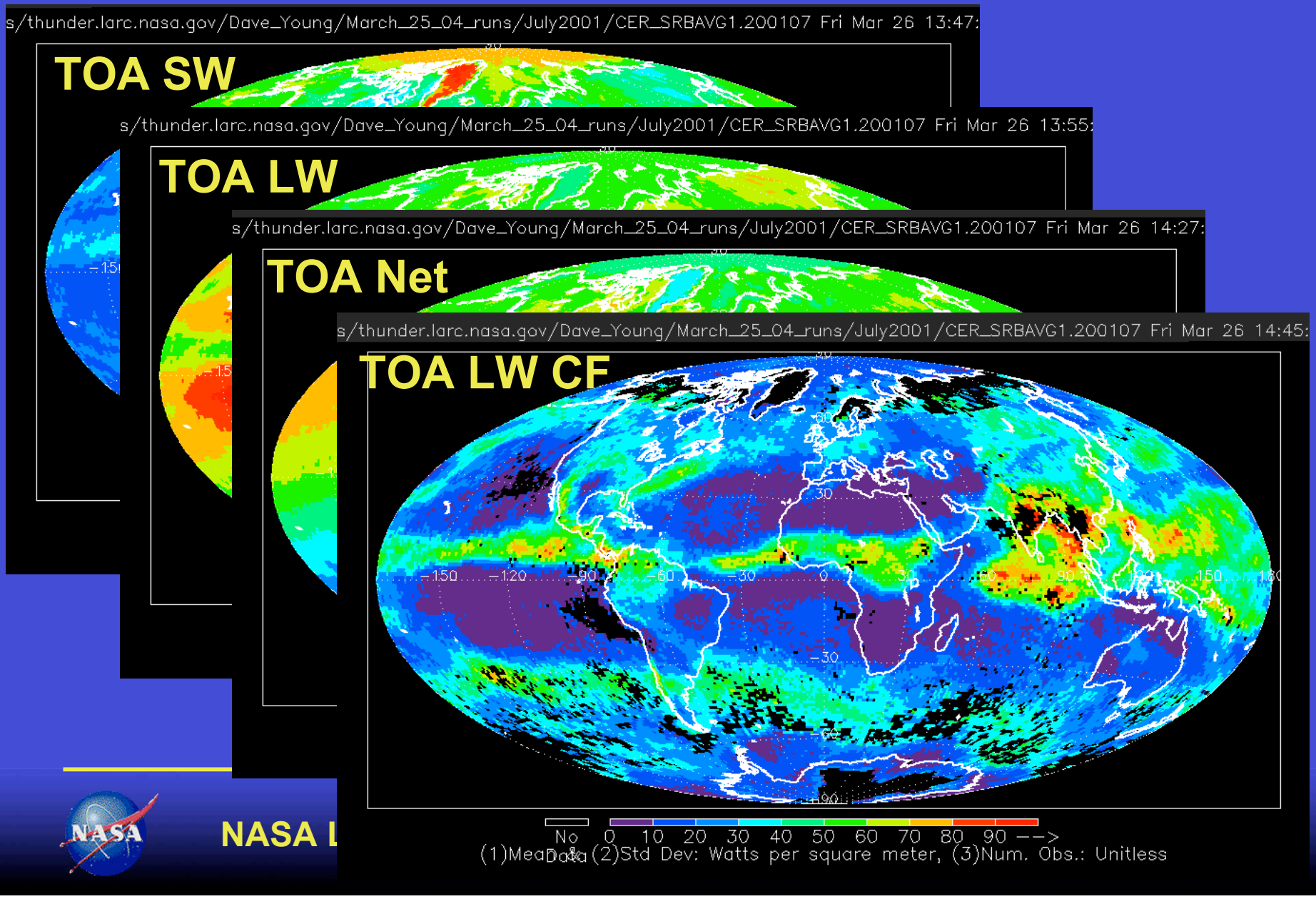


July SRBAVG Monthly Means



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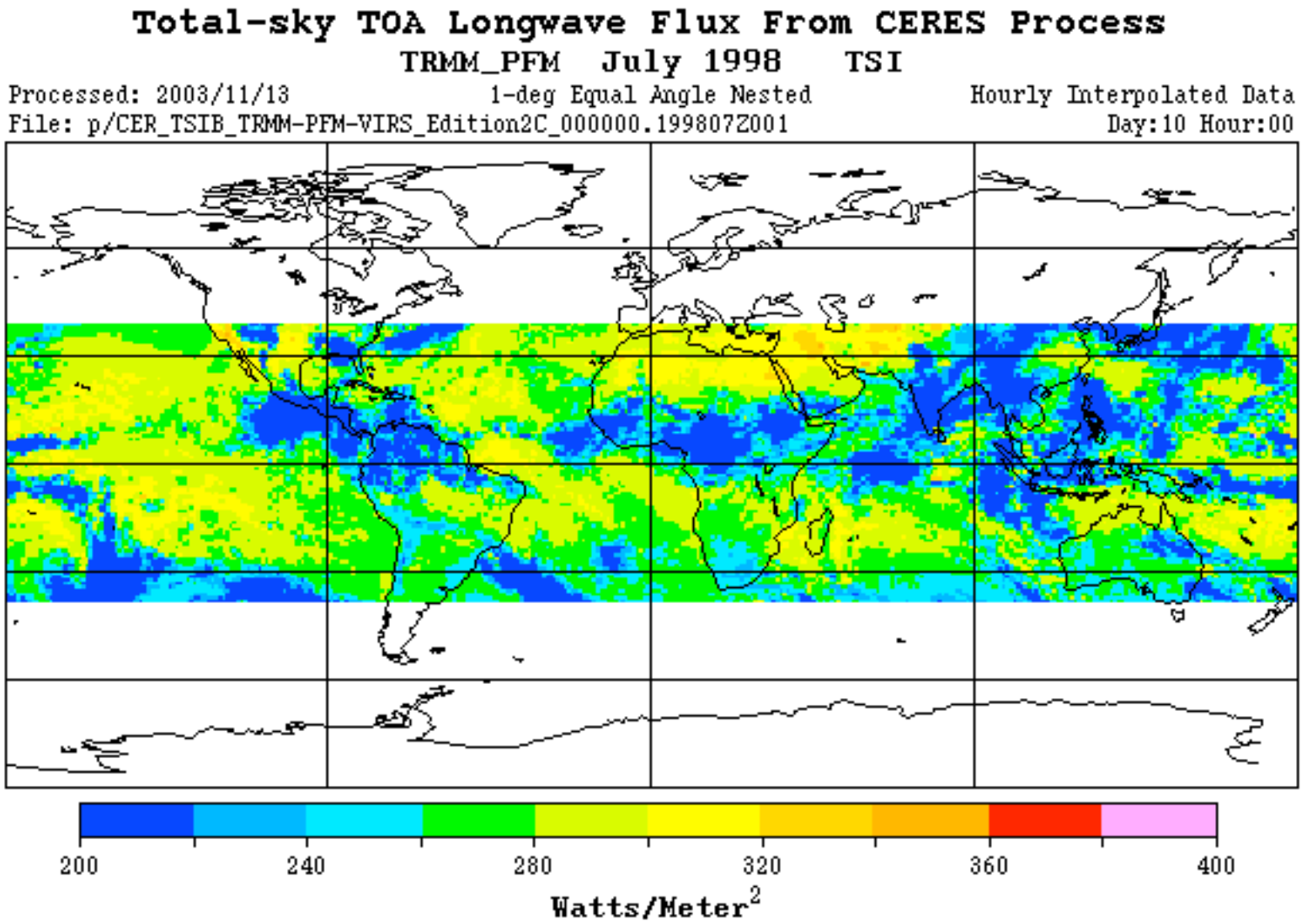
TISA Product Update: SYN and AVG/ZAVG

- SYN: Spatially/Temporally averaged product on 1° x 1° global grid
  - 3-hourly synoptic TOA, atmospheric, and surface fluxes + cloud data
- AVG/ZAVG monthly averaged SYN parameters
- Terra Beta2 SYN/AVG/ZAVG
  - Beta version tested for Mar00, Jan01, Apr01, Oct01
  - wait until GEO SW finalized to begin production


Total-sky TOA Longwave Flux From CERES Process
TRMM_PFM July 1998 TSI
Processed: 2003/11/13
1-deg Equal Angle Nested
Hourly Interpolated Data
File: p/CER_TSIB_TRMM-PFM-VIRS_Edition2C_000000.199807Z001
Day:10 Hour:00
200
240
280
320
360
400
Watts/Meter2

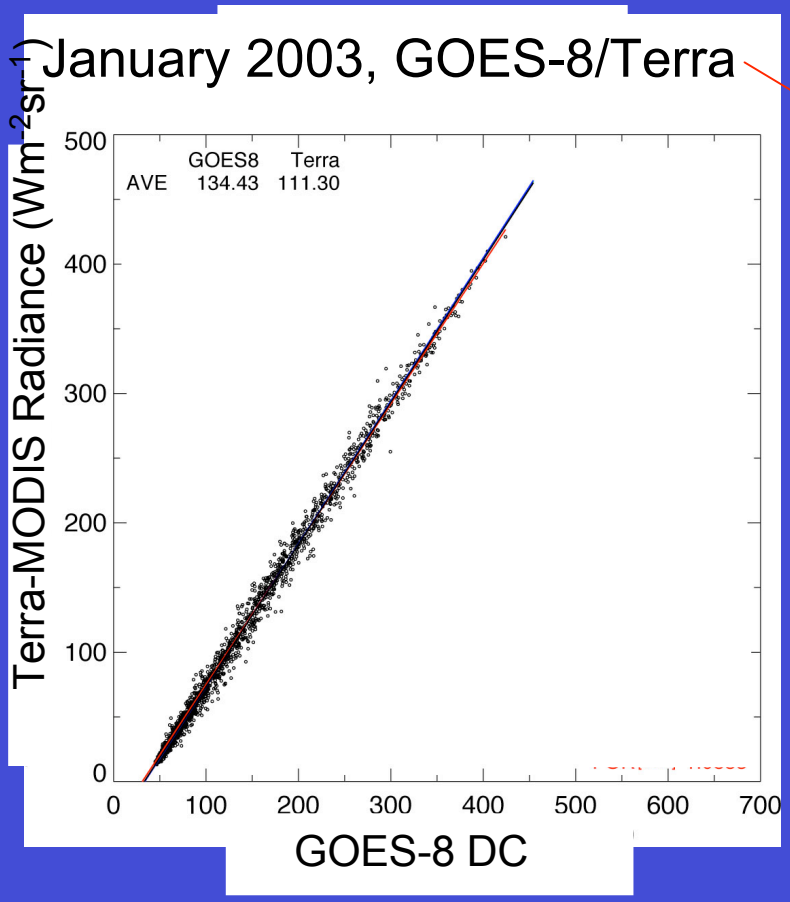
Using Geostationary Imager Data for Temporal Interpolation

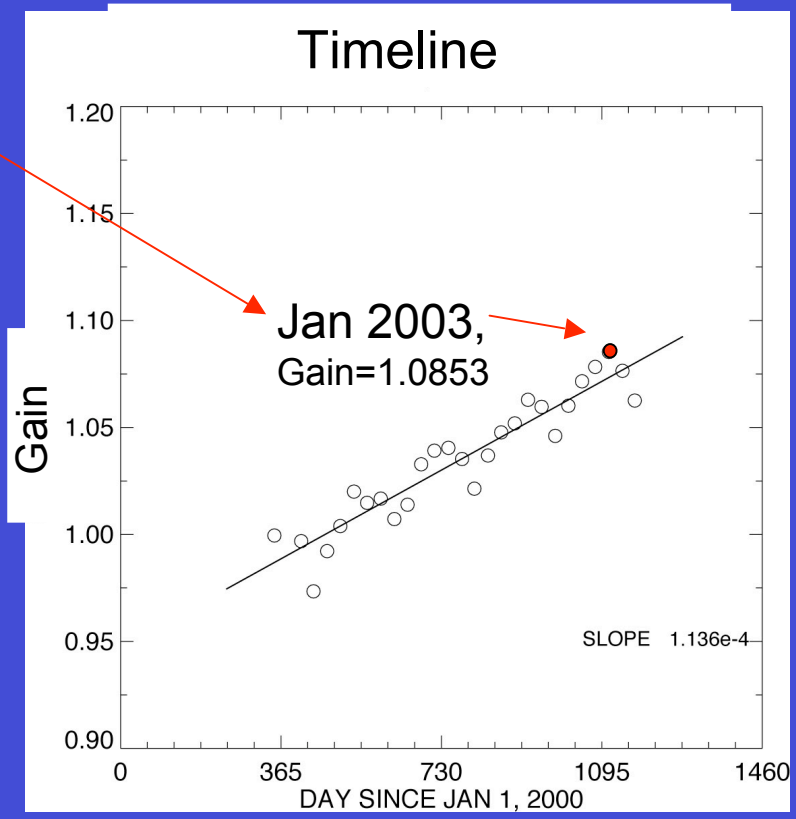
- Use geostationary data to define flux variations between CERES measurements
  - 3 hourly geostationary VIS and IR (8km) images
  - Algorithm needs to preserve CERES calibration
    - Algorithm needs to have consistent cloud properties with MODIS

Using Geostationary Imager Data for Temporal Interpolation

- GGEO SW
- Calibrate GEO visible radiances against MODIS
  - Geostationary VIS not calibrated
  - Calibrate over oceans to mitigate GEO spectral response function differences
  - Regress Co-located, Co-angled, Coincident radiances within 15 minutes
  - Validate by cross-calibrating GEO satellites

GOES-8 visible calibration with Terra-MODIS





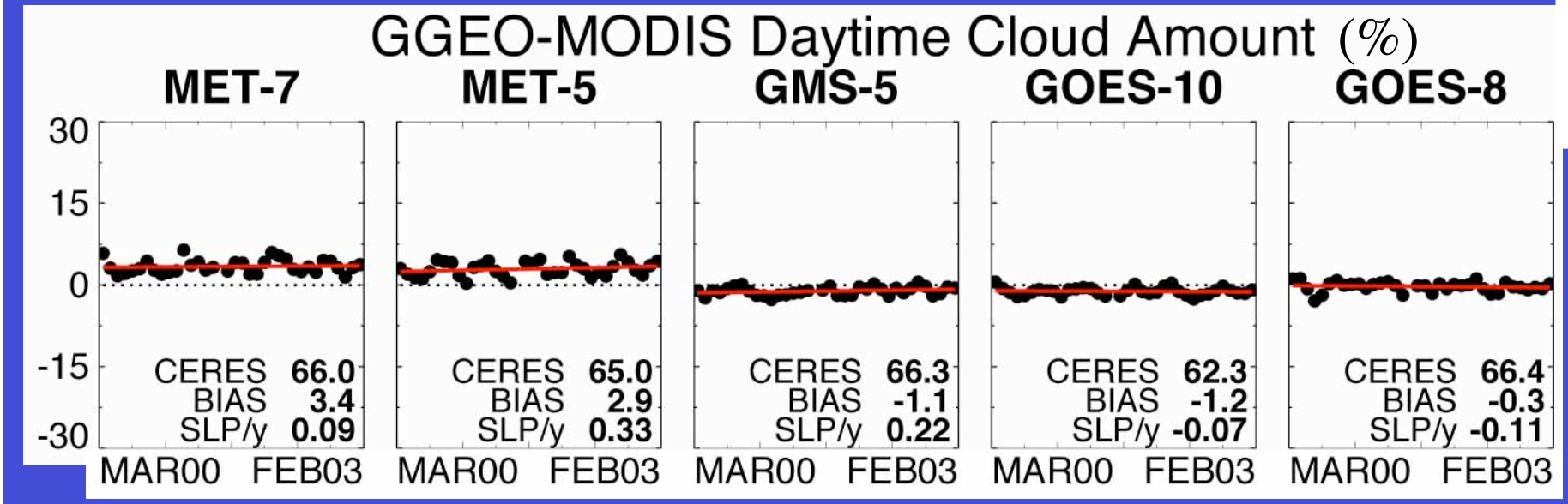
Degradation rate = 365*1.136e-4 = 4.15%/year

GGEO Cloud Product

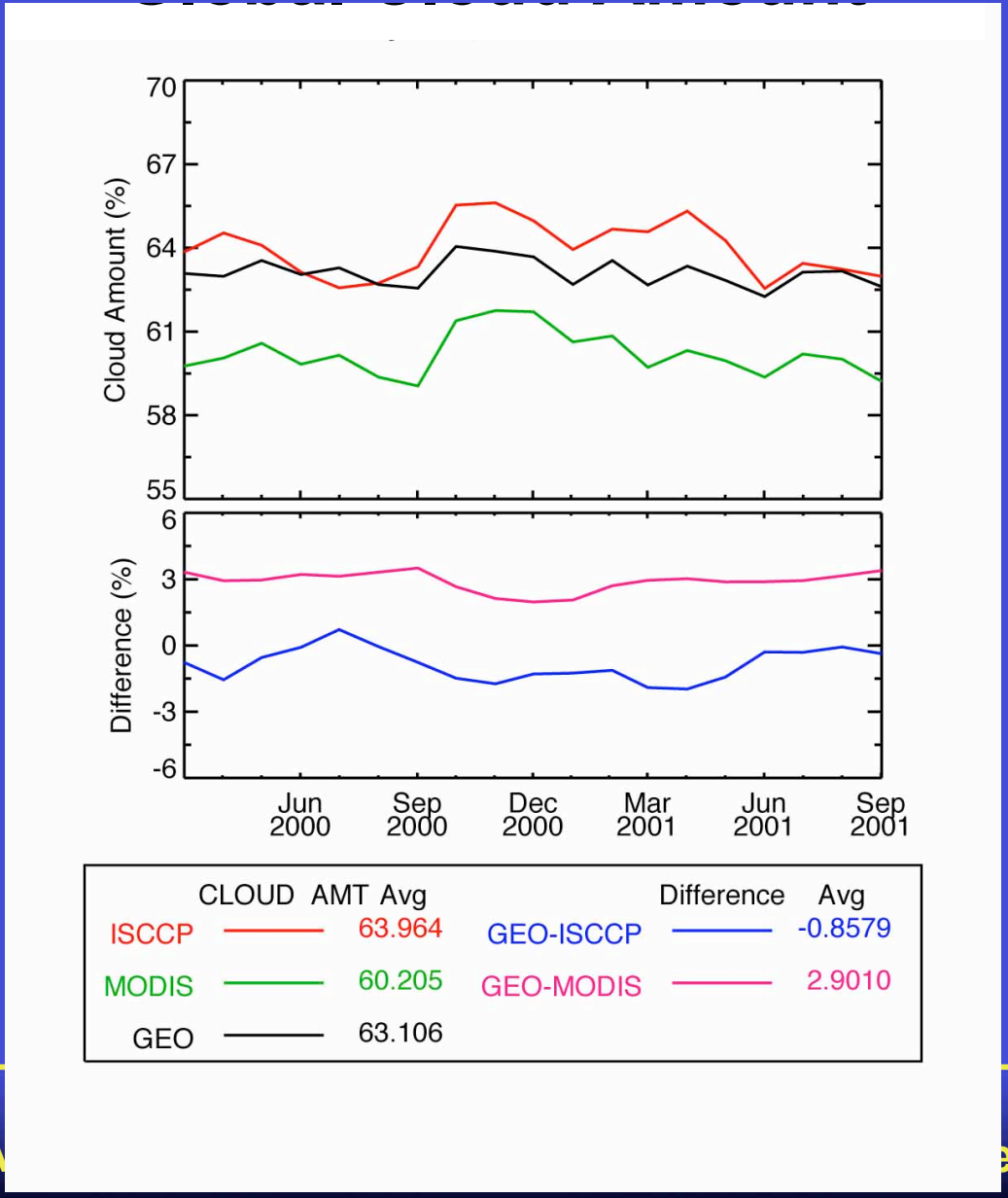
- Needed for SW interpolation & for monthly clouds
  - Necessary for ADM selection
- Uses IR/Vis retrievals (run as subset of CERES cloud algorithm)
- Uses CERES surface property maps and GEOS soundings
- 3-hourly Cloud Properties
  - Cloud Amount
  - Cloud Temperature
  - Cloud Height (using standard 4 CERES layers)
  - Optical Depth/Emittance (Daytime Only)
- The GGEO Product is not publicly released
  - Only monthly mean properties available
- Monitor cloud properties over time to validate visible calibration

GEO - MODIS monthly mean cloud fractions 3 year timelines over oceans

(Based on coincident matches)



Daytime 60°N to 60°S Cloud Amount



Using Geostationary Data for Temporal Interpolation of TOA Fluxes

- Narrowband GEO data converted to flux using NB-BB relationship & CERES TRMM ADMs
  - Based on angles, geo-type, cloud amount, phase, optical depth and GEO satellite
- Final fluxes are normalized to CERES observations
  - Using matched coincident CERES fluxes and GEO derived BB fluxes at multi-regional scale
  - Interpolated SW fluxes not normalized with CERES flux at the same hourbox, since meteorology may change significantly between 3 hourly GEO measurements
  - Normalization applied to total-sky flux
  - Use CERES regional clear-sky albedo during GEO clear-sky events
  - Normalized fluxes have no functionality with solar zenith angle but there is a some functionality with cloud amount

Using Geostationary Data for Temporal Interpolation of TOA Fluxes

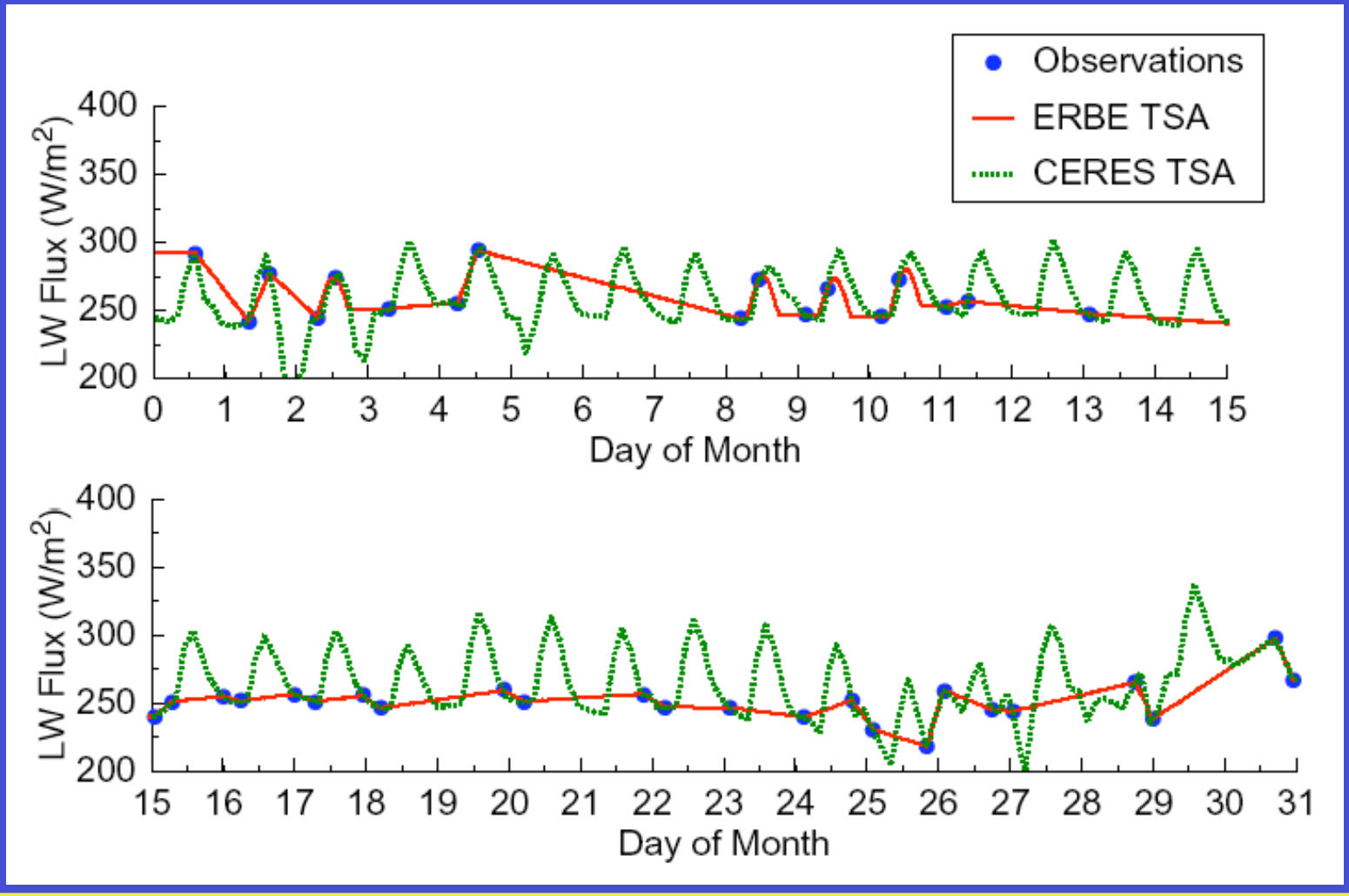
- GEO LW
  - GEO satellites have onboard IR calibration
  - IR radiances are converted to Narrowband (NB) fluxes using limb darkening
  - Apply empirical NB-BB relationship which includes a water vapor term
  - Normalize GEO derived interpolated fluxes with CERES at coincident times

CERES Temporal Interpolation Algorithms

- ERBE-like
  - Assumes constant meteorology between observations
  - LW
    - Linear interpolation
    - Simple diurnal sine function modeling over land regions
  - SW
    - Interpolation performed using directional models of albedo
    - Only 12 simple scene types
    - Scene identification based on LW and SW fluxes
- CERES nonGEO
  - Same approach as ERBE-like
    - Uses new CERES directional models (~600 scene types)
    - Uses MODIS cloud properties for scene identification
- CERES GEO
  - Normalize 3-hourly GEO derived BB fluxes with CERES at coincident times
    - Uses geostationary data to define flux variations between CERES measurements

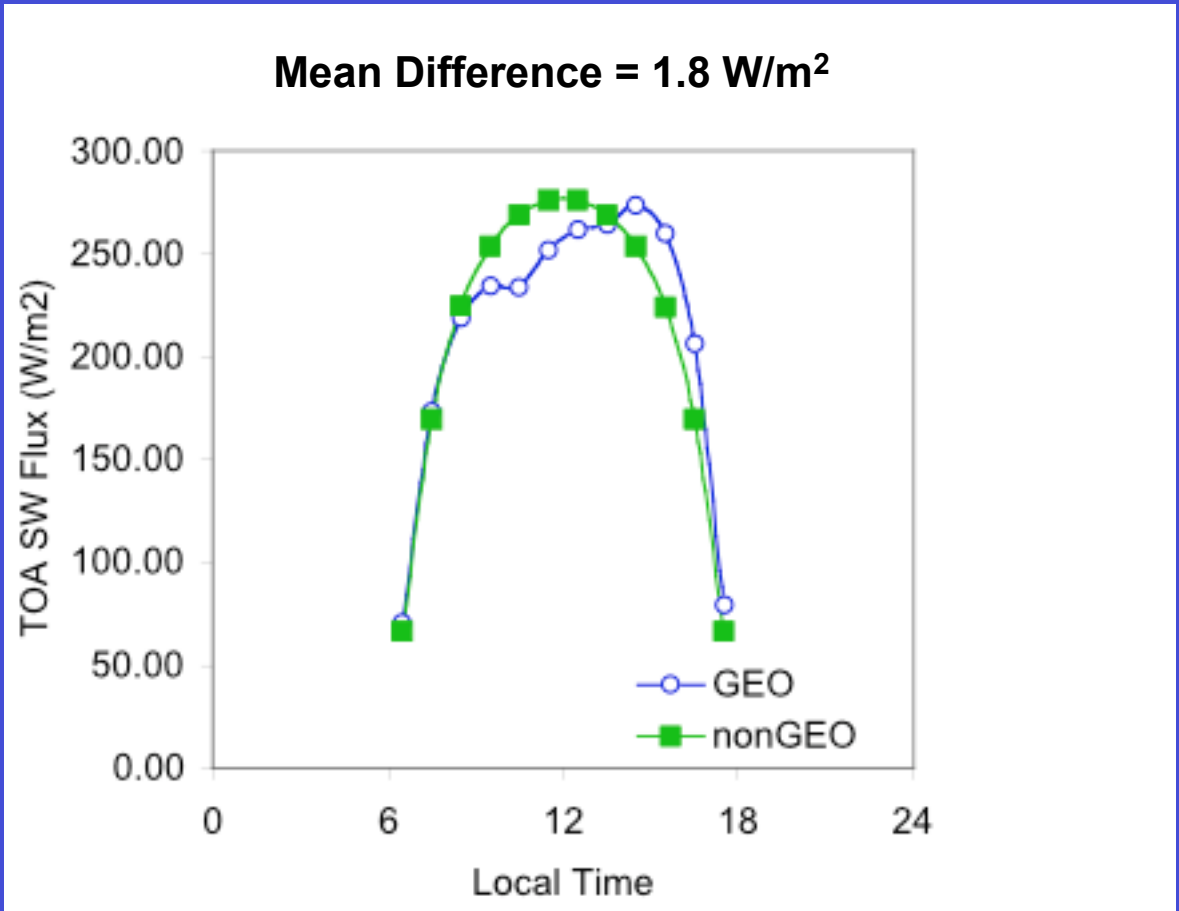
Temporal Interpolation of TOA LW Flux

January 1998 E. Sahara 24.5N 20.5E



GEO vs. nonGEO Monthly Mean Diurnal SW Flux

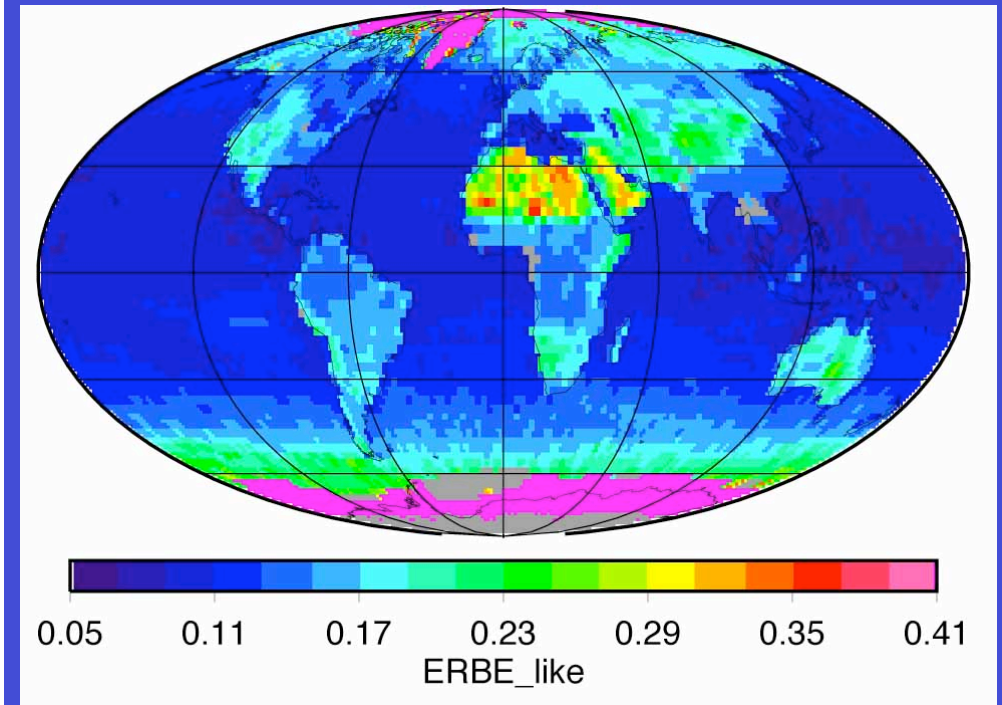
Equatorial Pacific Region CERES DRM



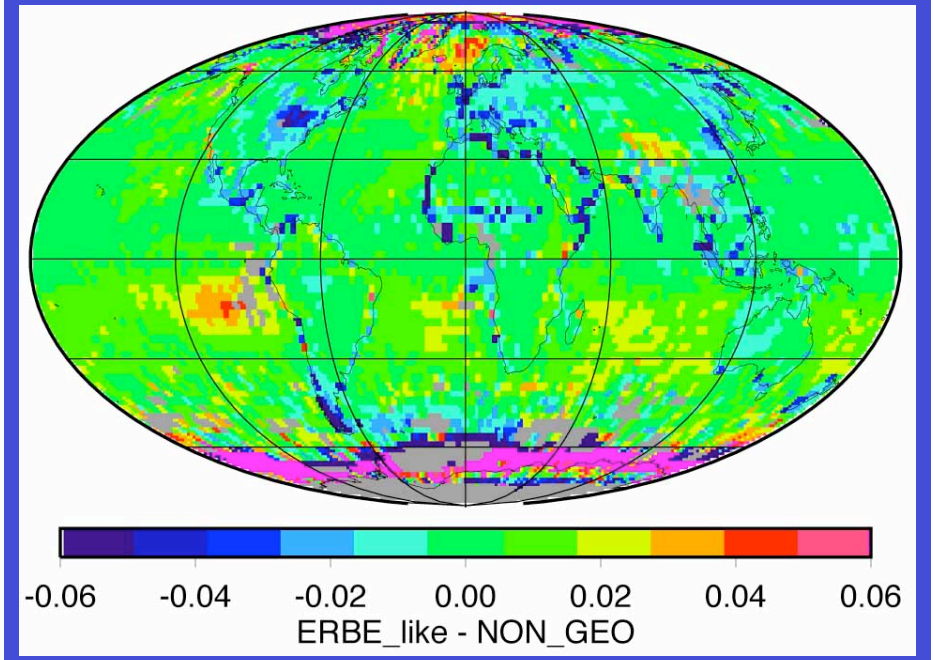
Improved Next Generation CERES Products

Aug 2002 Clear-sky Albedo

ERBE like mean

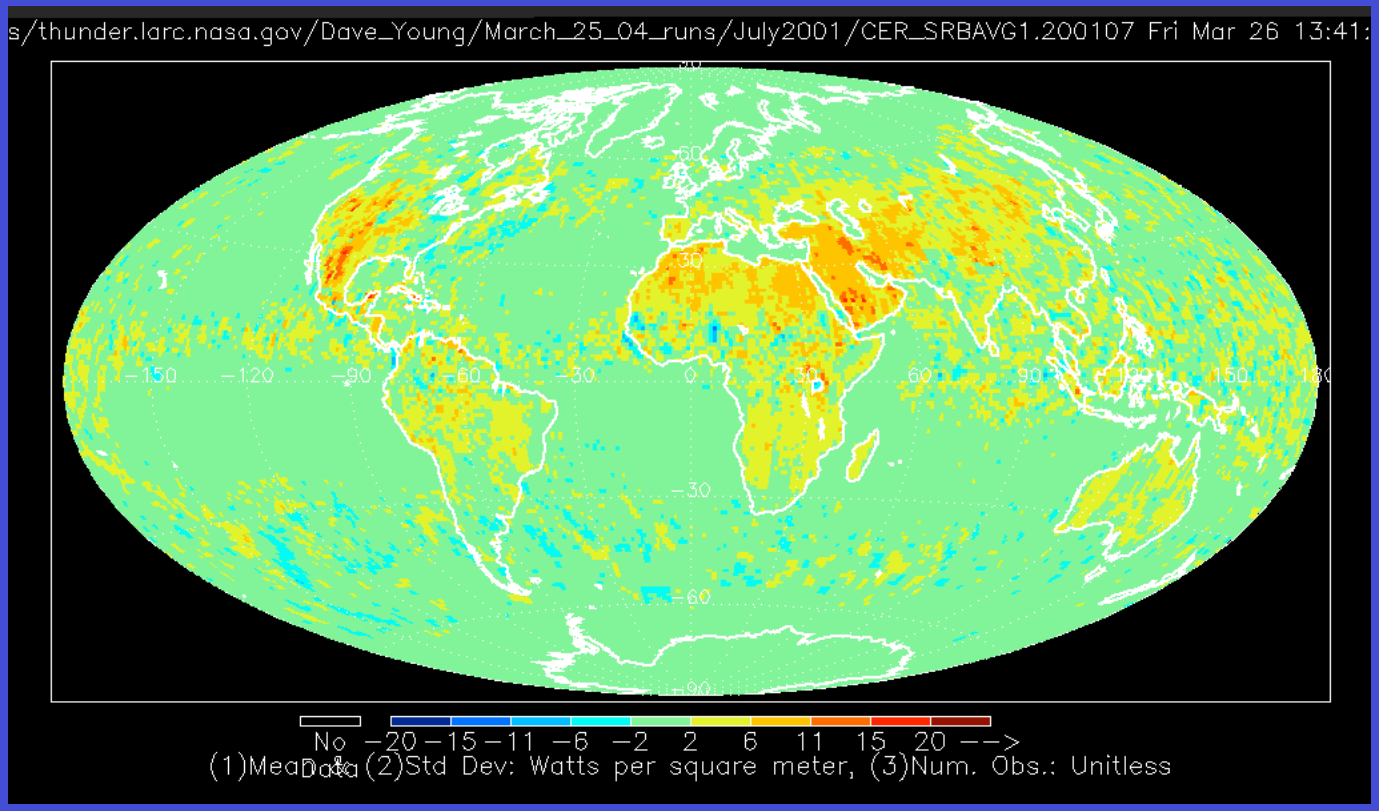


ERBE like - nonGEO



Adding GEO Data Decreases Temporal Sampling Errors
TOA LW Flux Change Terra FM-1 July 2001

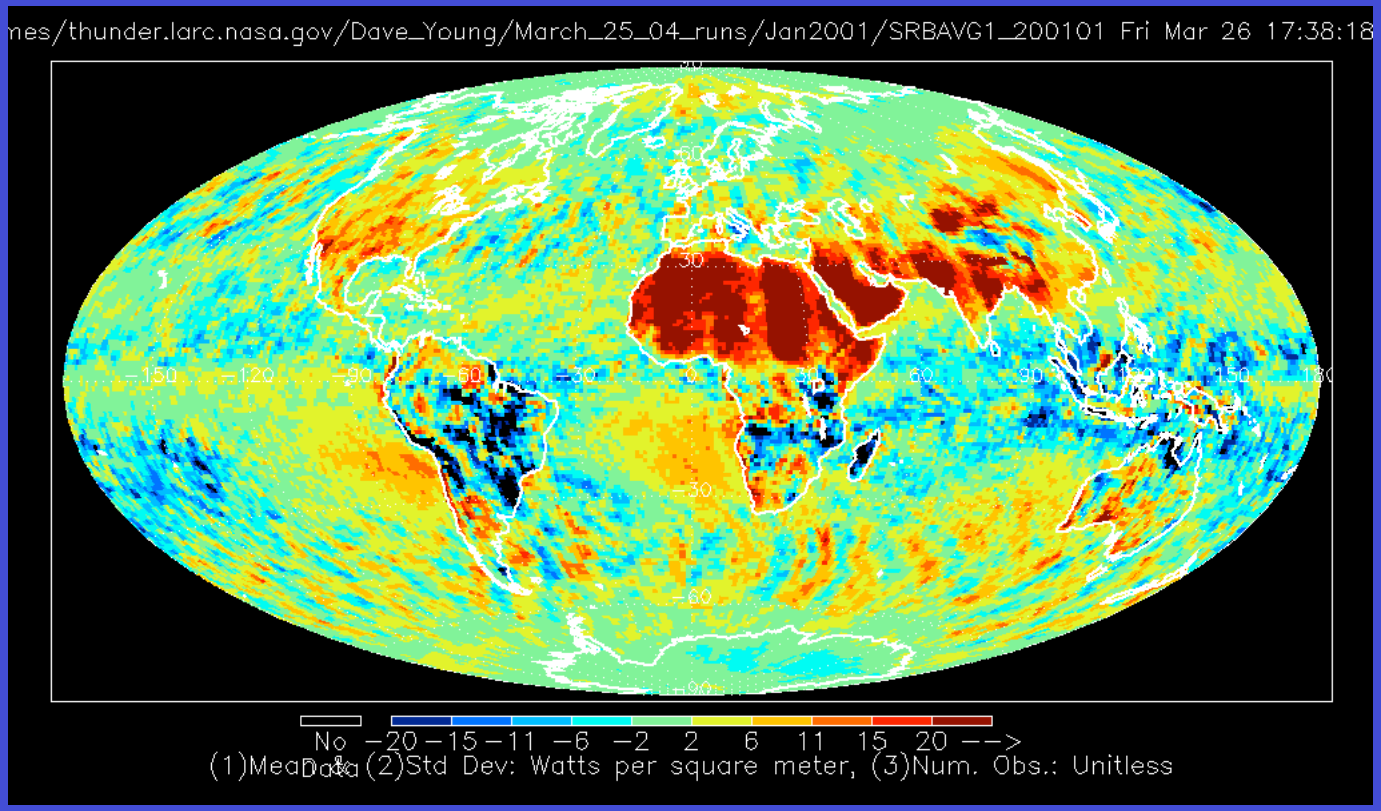
(nonGEO - GEO)



Decrease:
Yellow-red

Increase:
Blue

Adding GEO Data Decreases Temporal Sampling Errors
2:30 - 9:30 LT LW FLUX Terra FM-1 January 2001

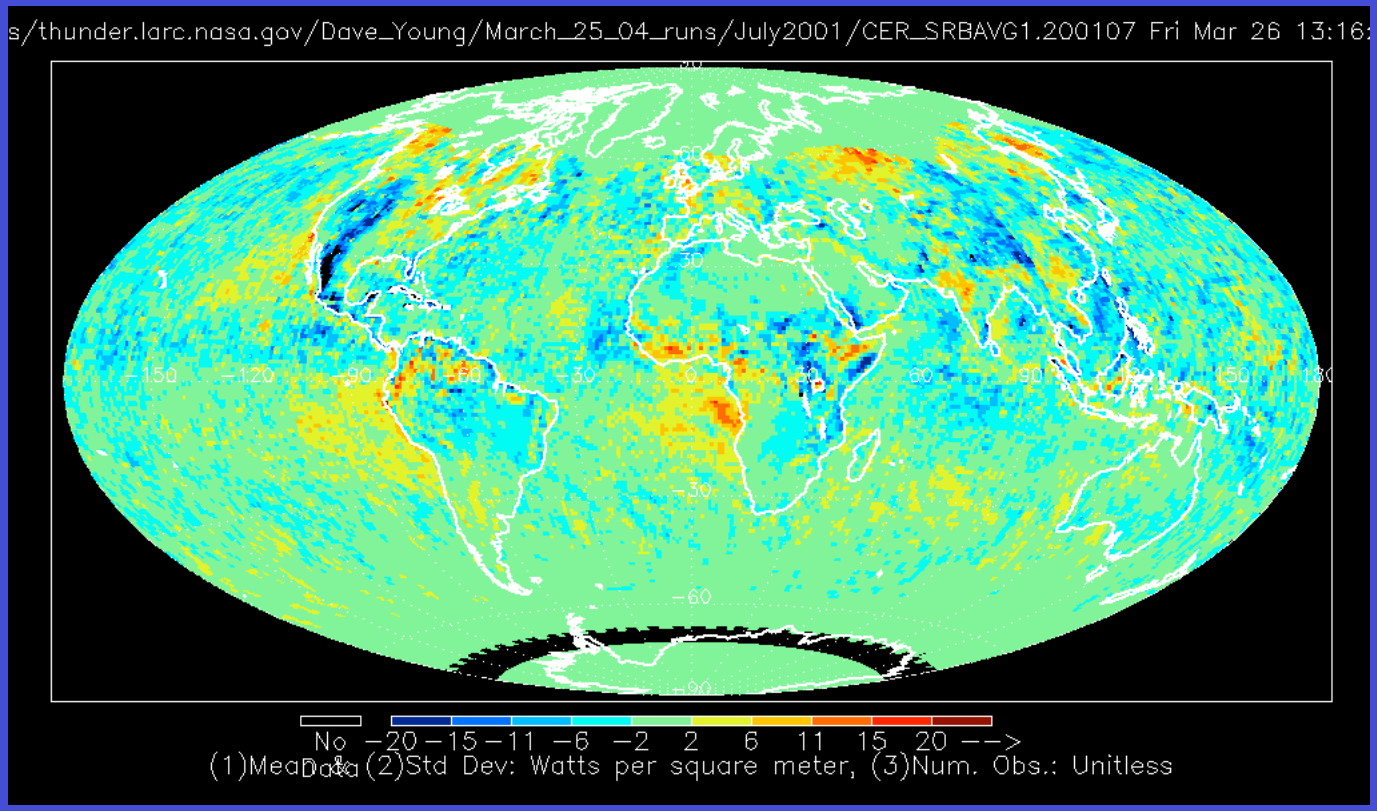


PM Higher:
Yellow-red

AM Higher:
Blue

Adding GEO Data Decreases Temporal Sampling Errors
TOA SW Flux Change Terra FM-1 July 2001

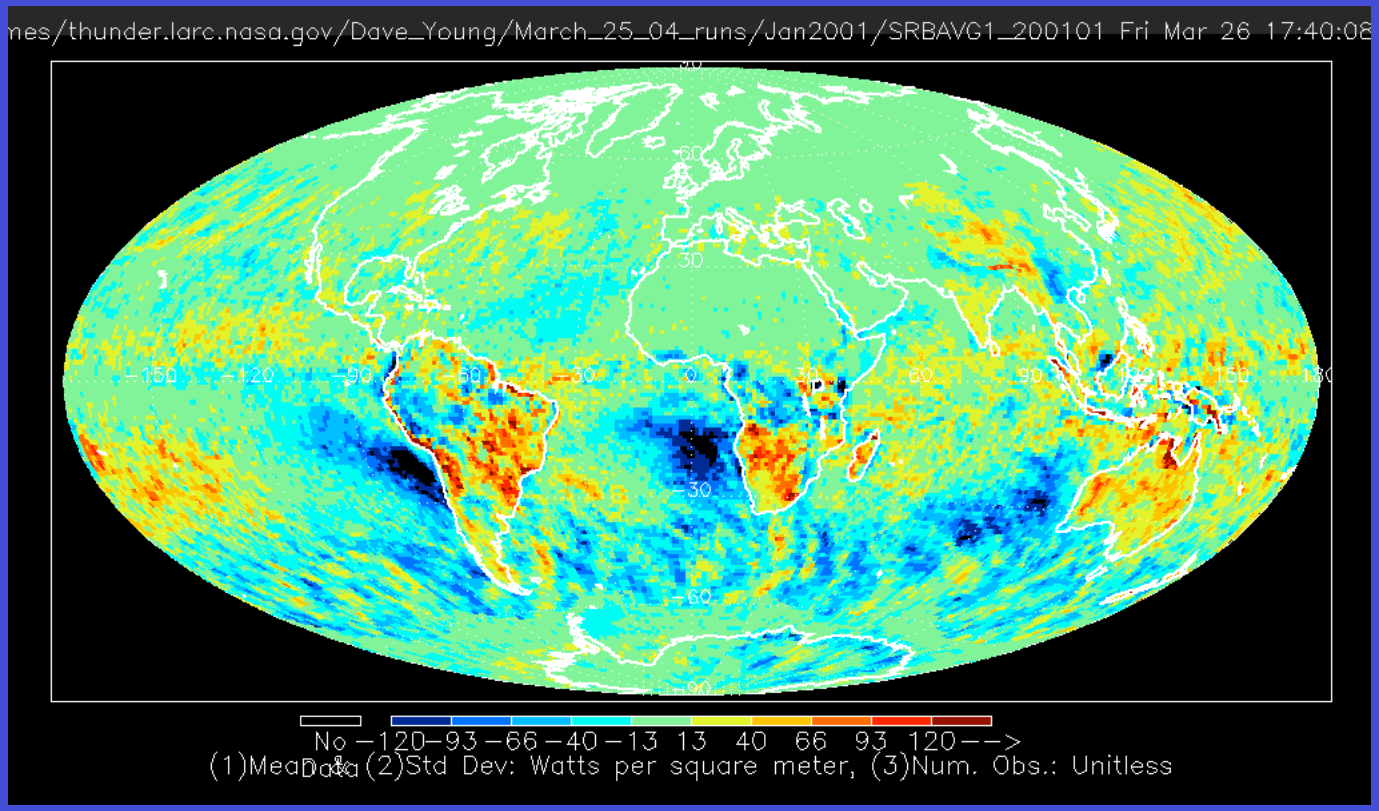
(nonGEO - GEO)



Decrease:
Yellow-red

Increase:
Blue

Adding GEO Data Decreases Temporal Sampling Errors
2:30 - 9:30 LT SW FLUX Terra FM-1 January 2001



PM Brighter: Yellow-red

AM Brighter: Blue

Validation

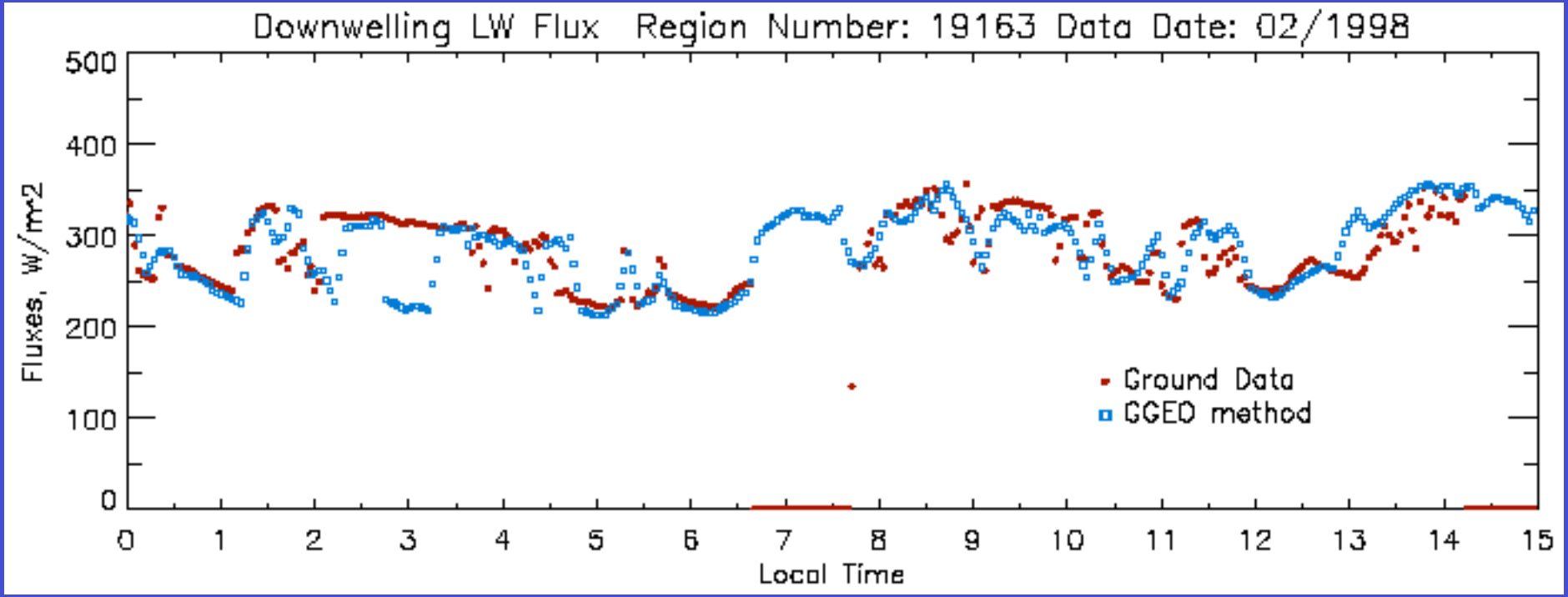
- GERB
  - Compare regional temporal interpolation with geostationary BB measurements onboard Meteosat-8
- Comparing Interpolation from 2 CERES Satellites
  - Can assess instantaneous errors or monthly means
  - March 2000 TRMM vs Terra
  - Terra vs Aqua
- Surface Flux
  - Compare surface fluxes derived from CERES measurements with surface radiometers

SRBAVG GEO and CAVE Monthly Surface Downwelling Longwave Flux Validation

- SRBAVG Model B (all-sky) LPLA (Gupta model)
  - Surface longwave fluxes independent from TOA
  - GEOS atmospheric state vertical profiles
  - GGEO (low) cloud base heights
- Monthly site surface fluxes from CAVE
  - ARM, SURFRAD, CMDL, and BSRN quality controlled surface radiometer networks
  - 3 years of monthly fluxes per station (Mar00 to Feb03)
  - 36 stations across the globe

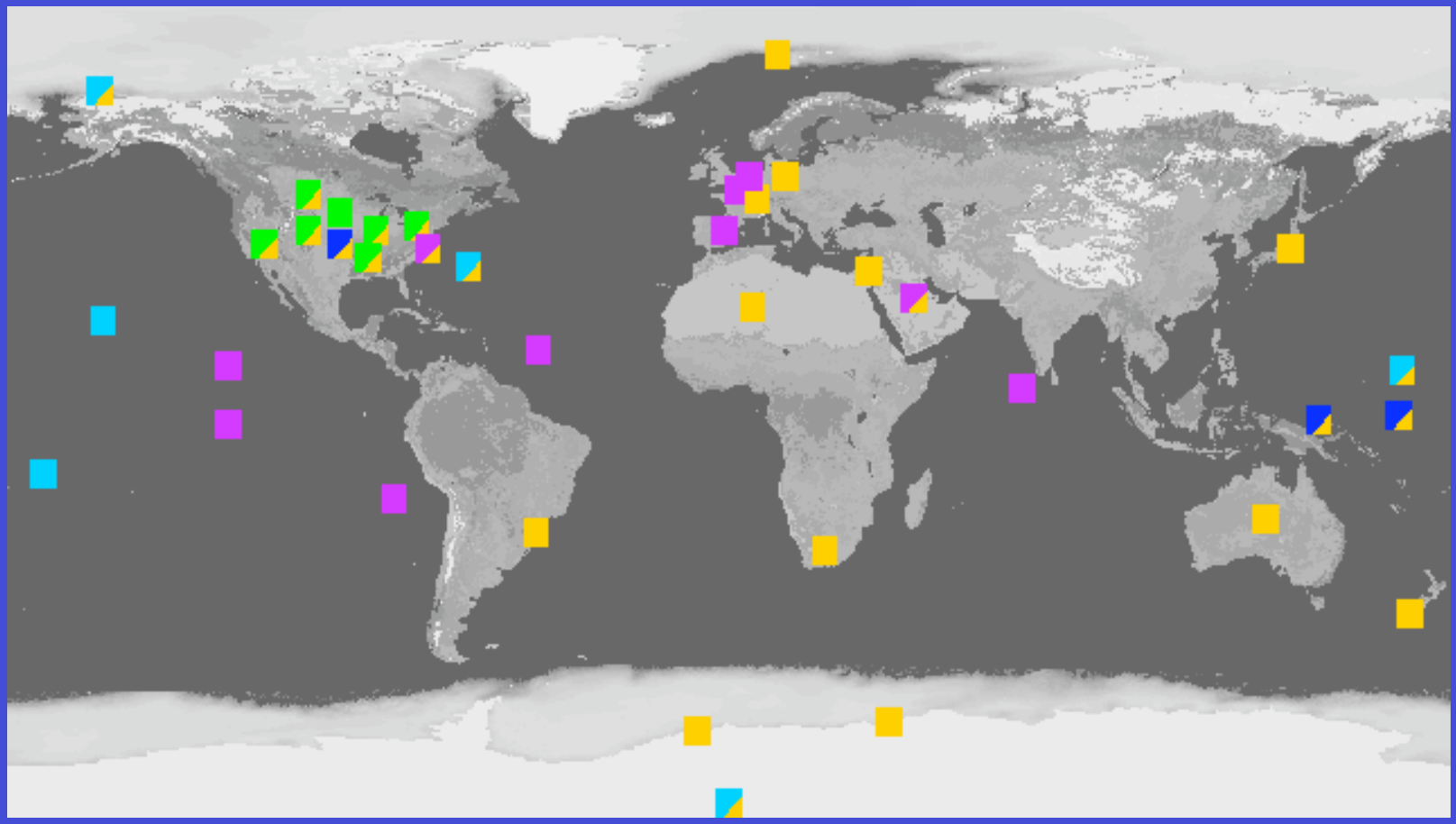
Comparison with Surface-Based Measurements

ARM SGP CF February 1998



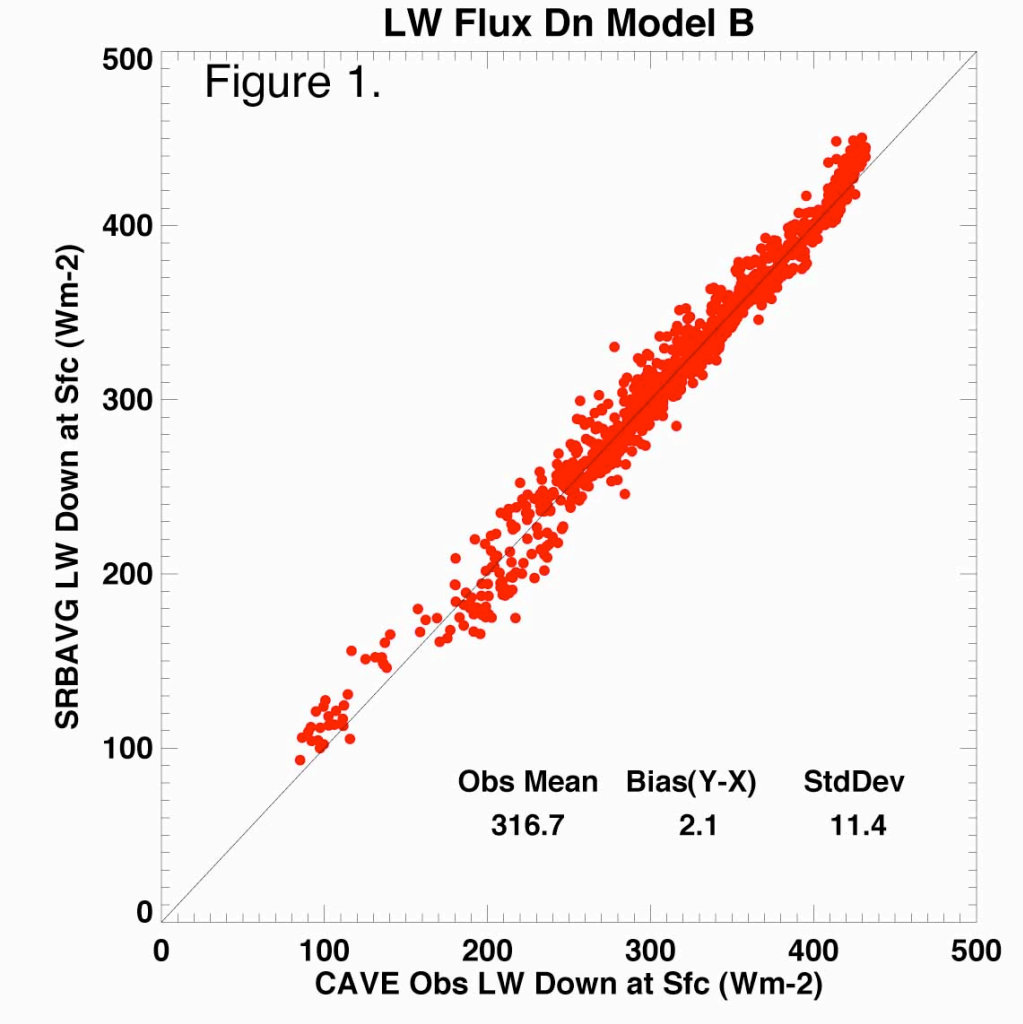
(W/m^2)	ΔFlux Bias	ΔFlux RMS
Instantaneous	-0.05	19
Interpolated	-2.9	25

CAVE surface stations



SRBAVG GEO and CAVE Surface Monthly Downwelling Longwave flux comparison

March 2000 to February 2003, 36 stations



- bias 2.1 Wm-2 or 0.7%
- rms error is 11.4 Wm-2 or 3.6%

- Biases likely where the GEOS profile is not representative of coastal, desert, or polar stations

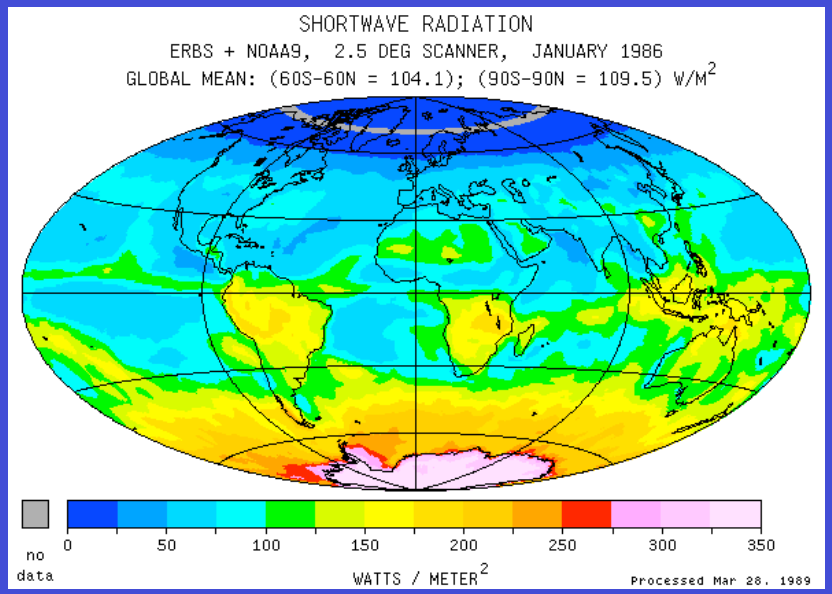
Remaining Issues

- SW Normalization
  - Remove dependency with cloud amount
- Final Validation
  - GERB
  - Aqua vs Terra
- Terra and Aqua SYN Product
- SRBAVG Additions
  - Daily means
  - ISCCP-like Cloud types based on optical depth and height

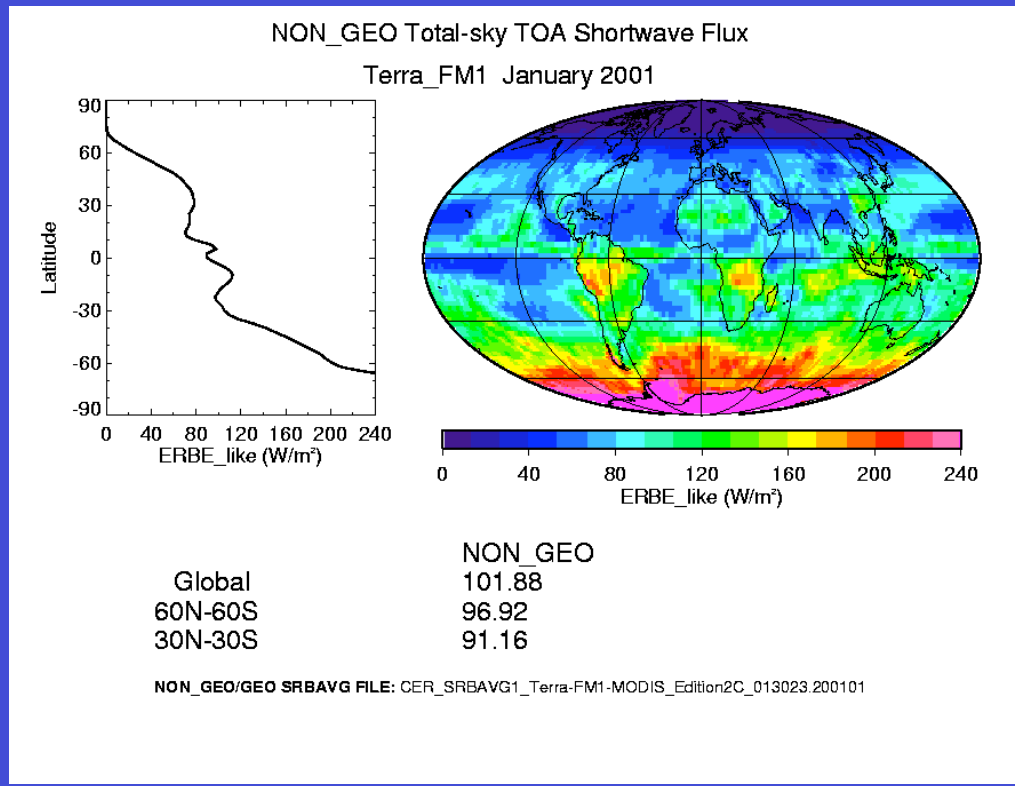
Global Mean Fluxes

SRBAVG Monthly Mean Flux and Cloud Property Images
(soon to be available on the web)

SW ERBE Jan86



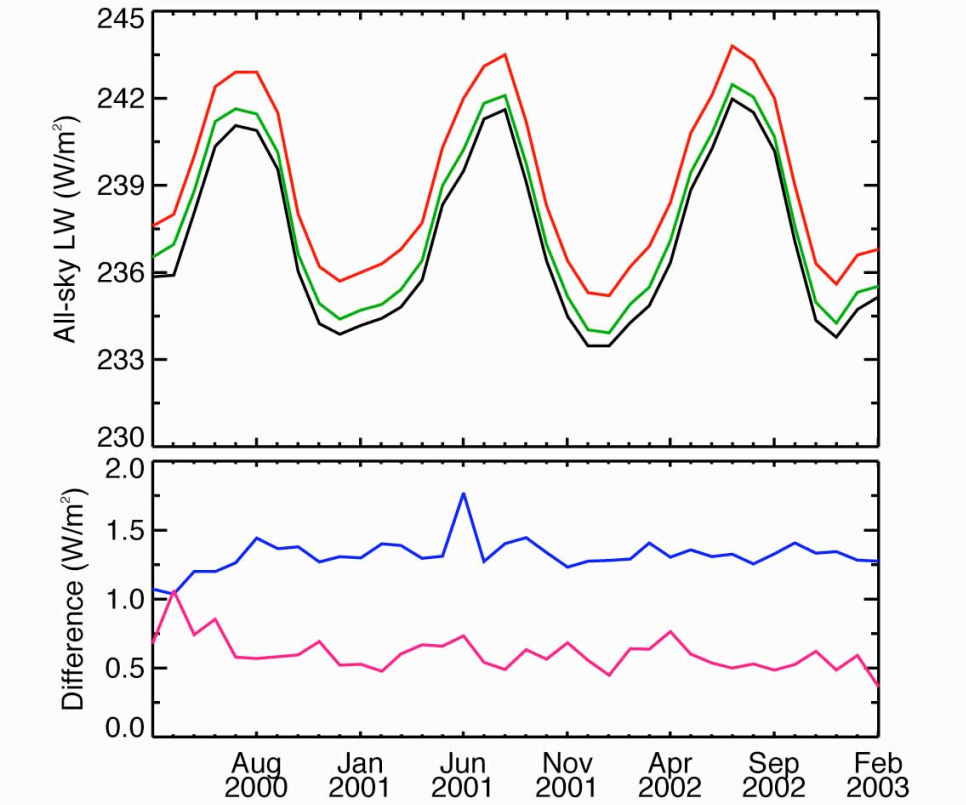
SW nonGEO Jan01



	NON_GEO
Global	101.88
60N-60S	96.92
30N-30S	91.16

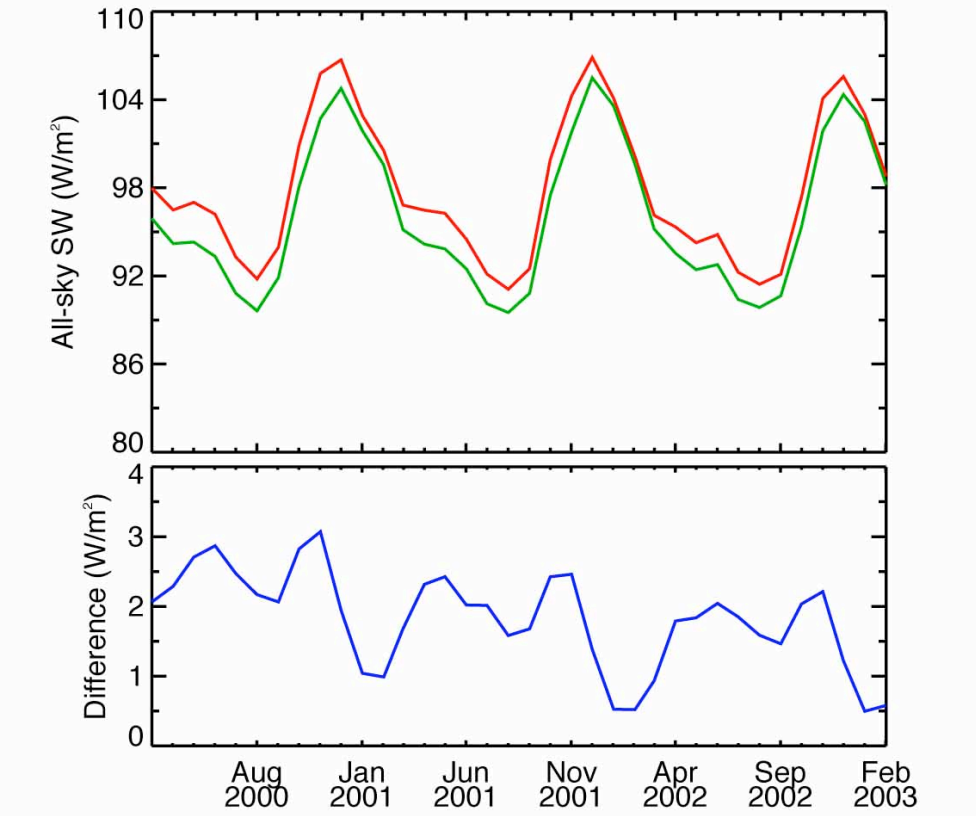
NON_GEO/GEO SRBAVG FILE: CER_SRBAVG1_Terra-FM1-MODIS_Edition2C_013023.200101

Global All-sky Longwave



ALL-SKY LW	Avg	Difference	Avg
ERBE	239.0	ERBE-NON_GEO	1.3
NON_GEO	237.7	NON_GEO-GEO	0.6
GEO	237.1		

Global All-sky Shortwave



ALL-SKY SW	Avg	Difference	Avg
ERBE	97.9	ERBE-NON_GEO	1.8
NON_GEO	96.1		

3 Year Global Mean TOA Fluxes

Wm^{-2}	CERES Mar 2000 – Feb 2003			1986-1988
All-sky	ERBE-like	nonGEO	GEO	ERBE
OLR	239.0	237.7	237.1	236.3
SW	97.9	96.1		100.1
NET	4.4	7.5		4.9

Summary

- There are 3 main data product groups
  - ERBElike
  - Surface + TOA products (SFC/SRBAVG)
  - Complete atmospheric radiative products (SYN/AVG/ZAVG)
- CERES attempts to model meteorology between CERES measurements using narrowband GEO data
  - Large-scale diurnal sampling errors removed
  - Maintains CERES absolute calibration and consistent cloud properties
  - Goal: regional monthly mean fluxes within 1 Wm^{-2}
- SRBAVG GEO SW due out soon
  - SYN products to follow later in year

Backup Slides

TISA Product Update: SFC

- Spatially averaged product on 1° x 1° global grid
  - Derived from SSF (CERES footprint data)
  - Instantaneous gridded
- Terra Edition 2C complete Mar00 to Dec03
  - Data Quality Summaries delivered
  - Processing to continue to Oct04
- Aqua Edition 1B SFC complete Jul02 to Aug03
  - Data Quality Summaries delivered
  - Processing to continue Jun04

TISA Product Update: FSW

- Spatially averaged product on 1° x 1° global grid
  - Derived from CRS (CERES footprint data + SARB)
  - Instantaneous gridded
- Terra Edition 2C complete Mar00 to May02
  - Data Quality Summaries delivered
- Aqua Beta1 complete Jul02 to Sep02

TISA Product Update: SRBAVG

- Spatially/Temporally averaged product on 1° x 1° global grid
  - Monthly mean TOA and surface fluxes + cloud data
  - nonGEO product includes only CERES fluxes with accompanying MODIS cloud properties
  - GEO product includes 3 hourly GEO derived BB fluxes and GEO cloud properties
- Terra Edition 2C complete Mar00 to Feb03
  - GEO LW included, GEO SW set to default
- Terra Edition 2D
  - will contain the GEO SW when algorithm is finalized
  - Will contain Terra snow directional models
- Aqua Edition 1B to wait until GEO SW finalized